

# **Clouds and the Earth's Radiant Energy System (CERES)**

## **Data Management System**

## **Software Design Document**

**Instantaneous SARB  
(Subsystem 5.0)  
and  
Synoptic SARB  
(Subsystem 7.2)**

# **ARCHITECTURAL DRAFT**

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## **Preface**

The Clouds and the Earth's Radiant Energy System (CERES) Data Management System supports the data processing needs of the CERES science research to increase understanding of the Earth's climate and radiant environment. The CERES Data Management Team works with the CERES Science Team to develop the software necessary to support the science algorithms. This software, being developed to operate at the Langley Distributed Active Archive Center (DAAC), produces an extensive set of science data products.

The Data Management System consists of 12 subsystems; each subsystem represents a stand-alone executable program. Each subsystem executes when all of its required input data sets are available and produces one or more archival science products.

The documentation for each subsystem describes the software design at various stages of the development process and includes items such as Software Requirements Documents, Data Products Catalogs, Software Design Documents, Software Test Plans, and User's Guides.

This version of the Software Design Document records the architectural design of each Subsystem for Release 1 code development and testing of the CERES science algorithms. This is a PRELIMINARY document, intended for internal distribution only. Its primary purpose is to record what was done to accomplish Release 1 development and to be used as a reference for Release 2 development.

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## Introduction

The Clouds and the Earth's Radiant Energy System (CERES) program is a key component of the Earth Observing System (EOS). The CERES instrument will provide radiometric measurements of the Earth's atmosphere from three broadband channels: a shortwave channel (0.2 - 5.0 $\mu$ m), a total channel (0.2 - 50 $\mu$ m), and an infrared window channel (8-12 $\mu$ m). The CERES instrument is an improved model of the Earth Radiation Budget Experiment (ERBE) scanner, which was flown aboard the Earth Radiation Budget Satellite (ERBS) from November 1984 until February 1990 in a 57-deg inclination orbit. During much of the same time period, additional ERBE scanner instruments flew on the National Oceanic and Atmospheric Administration (NOAA) Sun-synchronous, polar orbiting satellites NOAA-9 and NOAA-10. To reduce temporal sampling errors, ERBE successfully developed the strategy of flying instruments on Sun-synchronous, polar orbiting satellites with instruments on satellites with lower inclination orbits. Following the same strategy, the first CERES instrument is expected to be launched in 1997 aboard the Tropical Rainfall Measuring Mission (TRMM), a satellite with an orbital inclination of 35 degrees. Additional CERES instruments will be flown aboard the polar orbiting EOS-AM and EOS-PM platforms. The first EOS-AM platform is expected to be launched in 1998, while the first EOS-PM platform is expected to be launched in 2000. As an improvement to the ERBE strategy, CERES will include cloud imager data and other atmospheric parameters in order to increase the certainty of the data and improve the consistency between the cloud parameters and the radiation fields.

While the number of possible measurements per scan line is dependent upon platform, the scan line of a CERES instrument scanner will consist of up to 225 Earth-viewing measurements. The area viewed on the Earth for an individual measurement is referred to as a CERES footprint. The CERES Instantaneous Surface and Atmospheric Radiation Budget (SARB) Subsystem ([Subsystem 5.0](#)) consists of software to compute the vertical atmospheric profiles of shortwave and longwave radiative fluxes for the Earth-viewing CERES footprints in one hour segments from each satellite. For each footprint, this vertical profile will extend from the Earth's surface to the top-of-the-atmosphere (TOA) and will comprise the surface and atmospheric radiation budget. Given the TOA fluxes as derived by the CERES inversion process and stored on the Single Satellite Fluxes (SSF) product, this Subsystem will implement radiative transfer algorithms to produce an initial, or untuned, set of fluxes. Noting that the radiative transfer algorithms are imperfect, a set of TOA balanced fluxes will be computed by adjusting different input parameters, such as cloud properties and precipitable water. While an exact match is not likely, the initial fluxes are tuned until the results more closely agree with the CERES TOA. The tuned fluxes, along with the adjustments made to the initial fluxes and various parameters in the tuning process, are stored on the Cloud Radiative Swath (CRS) product.

The Synoptic SARB Subsystem ([Subsystem 7.2](#)) repeats this process on a regional, 3-hourly synoptic time basis. For this Subsystem, the CERES TOA fluxes are stored on the Time and Space Interpolated (TSI) product, and the flux profiles are stored on the Synoptic Radiative Fluxes and Clouds (SYN) product.

Once subsystem processing for a SARB Subsystem has been initialized, data from the input product are ingested one record (footprint for SSF, region for TSI) at a time, and then the vertical profiles are calculated and written to the output product. To calculate this vertical profile, ancillary data from the Meteorological, Ozone, and Aerosol (MOA), and the Surface Radiative Properties Climatology (SRC) input files are used. For the tuning process, additional input from the empirically precomputed Derivative Tables (DRIVTAB) product will be used. Once data for all of the SSF footprints have been processed, the SARB Subsystems generate quality control reports and perform the necessary finalization procedures.

The architectural design for the Instantaneous SARB Subsystem is discussed in [Section 5.0](#). The SSF and other input products required for Subsystem processing, along with the output products generated, are described in [Appendix A](#). The majority of the software used by the Synoptic SARB Subsystem is the same as that used by the Instantaneous SARB Subsystem. The differences between the two Subsystems are driven by the input and output products. [Section 7.2](#), therefore, only addresses the differences between the two Subsystems. [Appendix A](#) also contains descriptions of the input and output products associated with the Synoptic SARB Subsystem.

## **5.0 Instantaneous SARB (Subsystem 5.0)**

The Instantaneous SARB Subsystem begins processing by invoking Subroutine Start5 to open all of the input and output files used during execution. Also at this time, any applicable SSF header information is copied to the CRS header. It is expected that in Release 2 this initialization process will be more involved.

The SARB Subsystem begins processing by invoking Subroutine Start5 to open all of the input and output files used during execution. It is expected that in Release 2 this initialization process will be more involved.

Each record of data contained on the primary input product is read and a check for any read errors is performed. MOA data for the CERES region associated with the input record are then retrieved. Data from the input source that are required by the Fu-Liou radiative transfer model and tuning process are loaded into variables included in the Module SARB\_Var. These data are listed in [Table 5-1](#).

Prior to invoking the Fu-Liou radiative transfer model, vertical profiles of temperature, specific humidity, and ozone mixing ratio, all a function of pressure, must be prepared. These vertical profiles are subsets of the profiles obtained from the MOA, along with the addition of new levels that correspond to the top and bottom pressures of the clouds contained on the input product. Unlike the order of the profiles on the MOA, the first level in the profiles used by the Fu-Liou model corresponds to the TOA (1 hPa), and the last level corresponds to the surface. The meteorological and ozone mixing ratio data for the new levels are linearly interpolated from the existing MOA data.

Table 5-1. Input Data Required by Fu-Liou Radiative Transfer Model and Tuning Process

PARAMETERS	SOURCE
Cloud fraction for each cloud height category	SSF
Cloud optical depth for each cloud height category	SSF
Cloud effective temperature for each cloud height category	SSF
Cloud liquid particle size for each cloud height category	SSF
Cloud ice particle size for each cloud height category	SSF
Cloud top pressure for each cloud height category	SSF
Cloud liquid water path for each cloud height category	SSF
Cloud ice water path for each cloud height category	SSF
Mean phase for each cloud height category	SSF
Surface latitude and longitude coordinates	SSF
Solar zenith angle	SSF
Earth-Sun distance	SSF
Clear-sky 11 $\mu$ m radiance, mean and standard deviation	SSF
CERES LW TOA flux	SSF
CERES SW TOA flux	SSF
Skin temperature	MOA
Pressure level profile	MOA
Temperature profile	MOA
Specific humidity profile	MOA
Precipitable water	MOA
Column ozone	MOA
ERBE scene type	SSF
Ozone mixing ratio profile	MOA
Aerosol optical depth	MOA
Surface albedo/emissivity	SRC/SSF

In addition to adding the cloud top and bottom levels to the profiles, which layers in the profile contain which cloud height category must also be tracked. Subroutine `WithCloud_Profile_Build` stores this information in `CCLyr_Idx (I, J)`. `I` indicates the cloud height category (1=high, 2=upper middle, 3=lower middle, 4=low), and `J` equal to 1 indicates the profile layer corresponding to the top of the cloud, while `J` equal to 2 indicates the bottom layer. For example, suppose that the top pressure of a cloud for the second cloud height category corresponds to level 15, and the bottom pressure corresponds to level 18. The cloud is contained in layers 15, 16, and 17, and `CCLyr_Idx (2, 1)` equals 15 and `CCLyr_Idx (2, 2)` equals 17. (Note the difference between the terms "level" and "layer." A layer is between two levels.)

The Fu-Liou radiative transfer model also requires the water content and particle size for each cloud height category contained on the input product. While the cloud particle size is obtained from the input product, the water content must be derived from the cloud optical depth. Subroutine `OptDepth_LWC` drives this derivation. While the information for both ice and liquid water conditions is available on the input product, the Fu-Liou model cannot handle a mix. Consequently, if the phase mean for a cloud height category indicates mostly liquid water, then the water content and particle size values are assigned the variables associated with liquid water, and the variable associated with ice water are assigned the value of zero. Likewise, if the phase mean indicates mostly ice water, the values of the variables associated with liquid water are set to zero.

For each input record the Fu-Liou model is called for the clear-sky condition, and then for each cloud height category contained on the input product record. For each call to the model, arrays of pressure levels, temperature, specific humidity, ozone mixing ratio, water content, and particle size are given. For the clear-sky condition, the water content and particle size arrays are set to zero. For subsequent calls for each existing cloud height category, only the water path and particle size array values corresponding to the profile layers encompassed by that cloud are defined with values other than zero. The definition of these array values takes place in Subroutine `FL_Call`. Also required by the Fu-Liou model are the cosine of the solar zenith angle, surface emissivity, surface albedo, surface skin temperature, the solar constant, aerosol optical depth, and an aerosol scene type (maritime, land, or urban).

After this process is completed for the initial flux calculation, Subroutine `Tune_Drv` invokes the tuning code. The tuning code will adjust the values for various parameters such as the surface albedo, skin temperature, and cloud temperatures. Subroutine `Temp_Pres` converts the adjusted cloud temperatures to adjusted cloud top and bottom pressures. The vertical profiles of temperature, specific humidity, and ozone mixing ratio are then rebuilt to include the tuned cloud levels instead of the cloud levels read from the SSF. With the newly adjusted data, the Fu-Liou model is again invoked for the clear-sky condition and each existing cloud height category.

The SARB Subsystems calculate flux profiles at more levels than can be stored on the output products. Subroutine `Selflx` isolates the flux values at predetermined archival levels from the profiles. After both the initial and tuned flux profiles are calculated, Subroutine `Prep_Output` determines the differences between the initial and tuned calculations at the archival levels and stores these differences in the variables written to the output product.

Figure 5-1 is a flow diagram of the SARB Subsystem processing. Figure 5-2 is the structure chart of the routines used during SARB Subsystem processing. Brief descriptions of the function of each subroutine, along with in which FORTRAN 90 modules the routines are contained, are given in Table 5-2.

As stated previously, the Synoptic SARB Subsystem uses much of the same code as the Instantaneous SARB Subsystem. The primary differences are the ingestion of the input data and the writing of the output data. The code to build the pressure level profile, interpolate the MOA data, adjust tuning parameters, and invoke the Fu-Liou Model is common to both Subsystems. Subroutines that are used by both Subsystems are also noted in Figure 5-2.

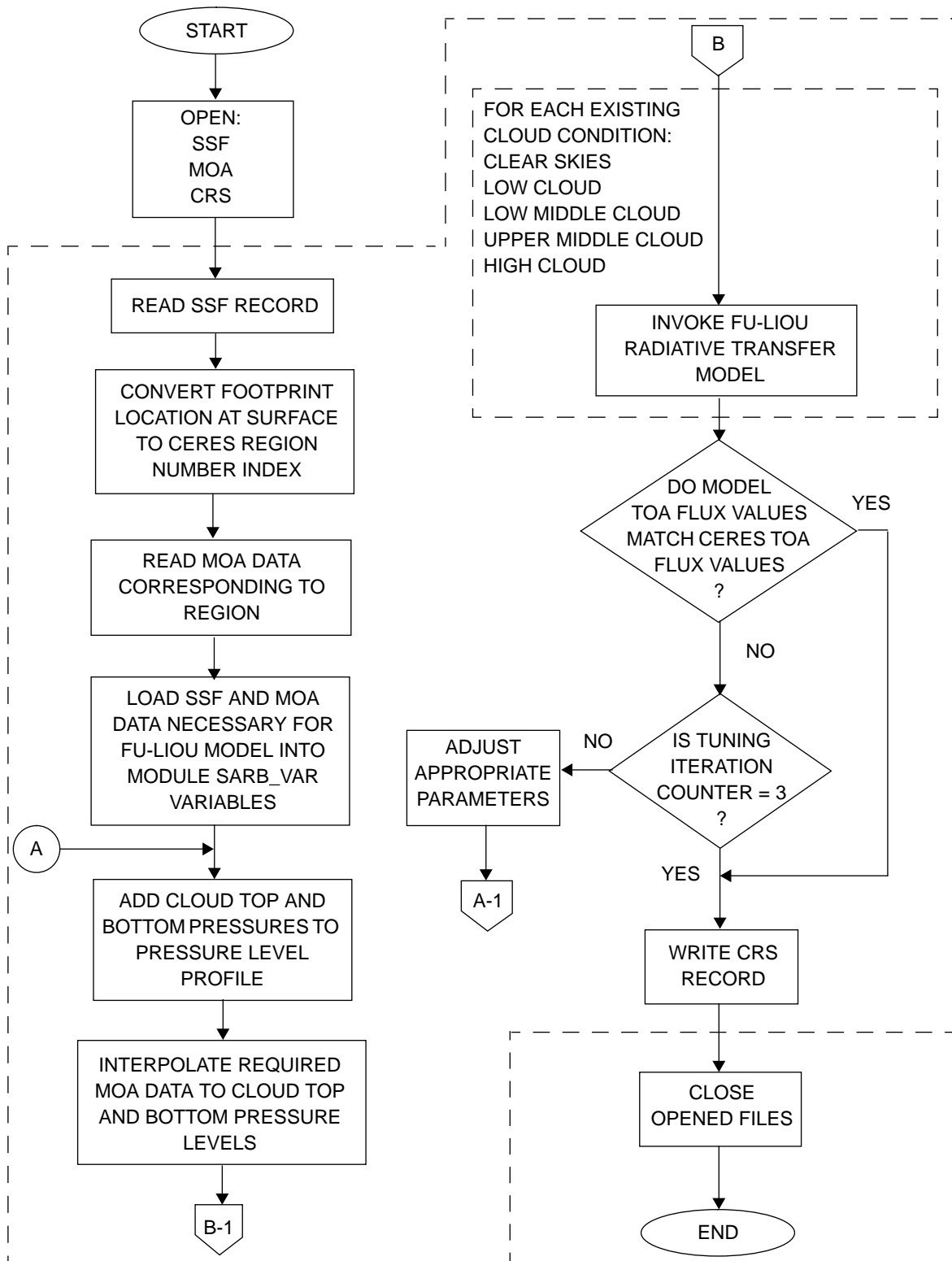
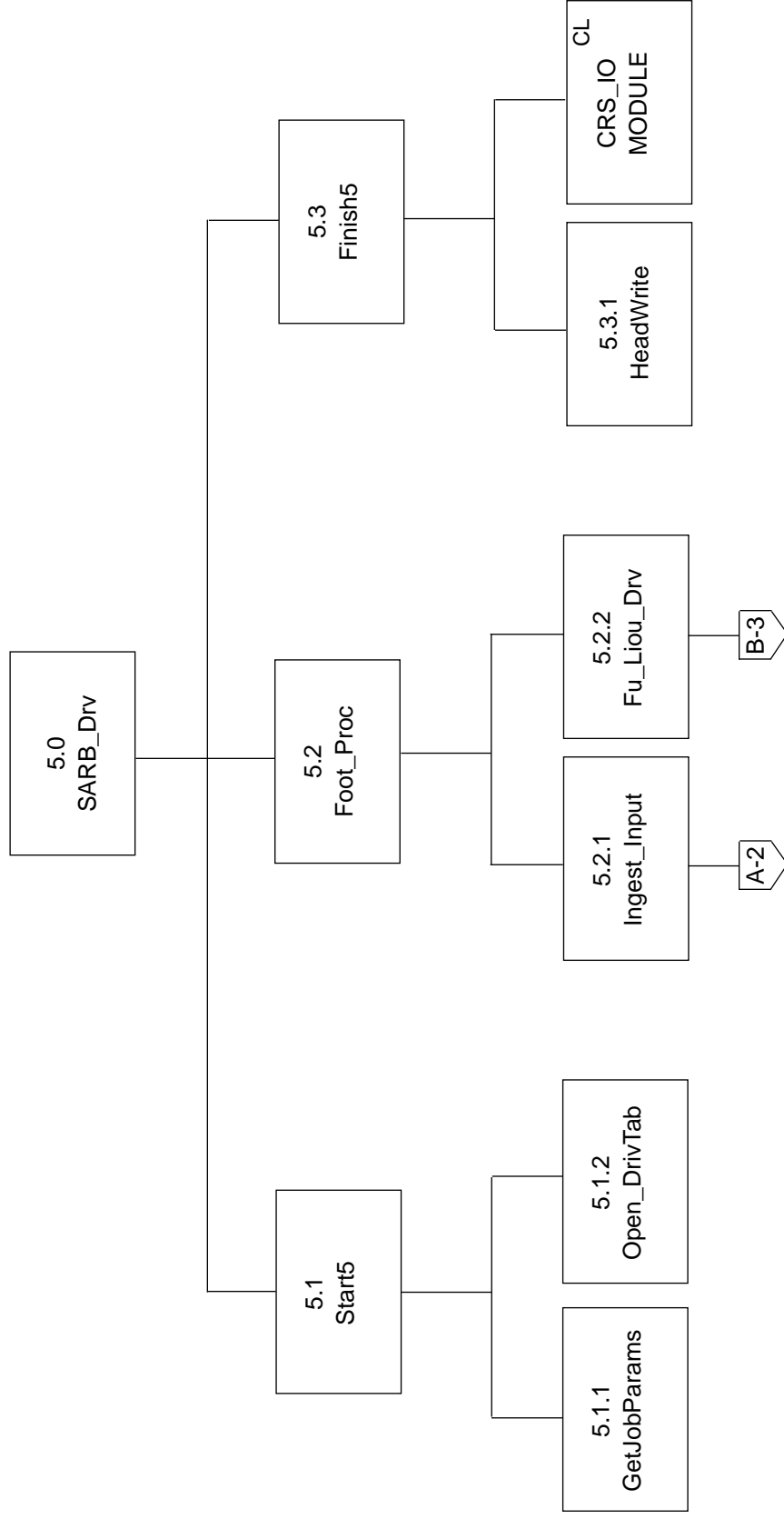
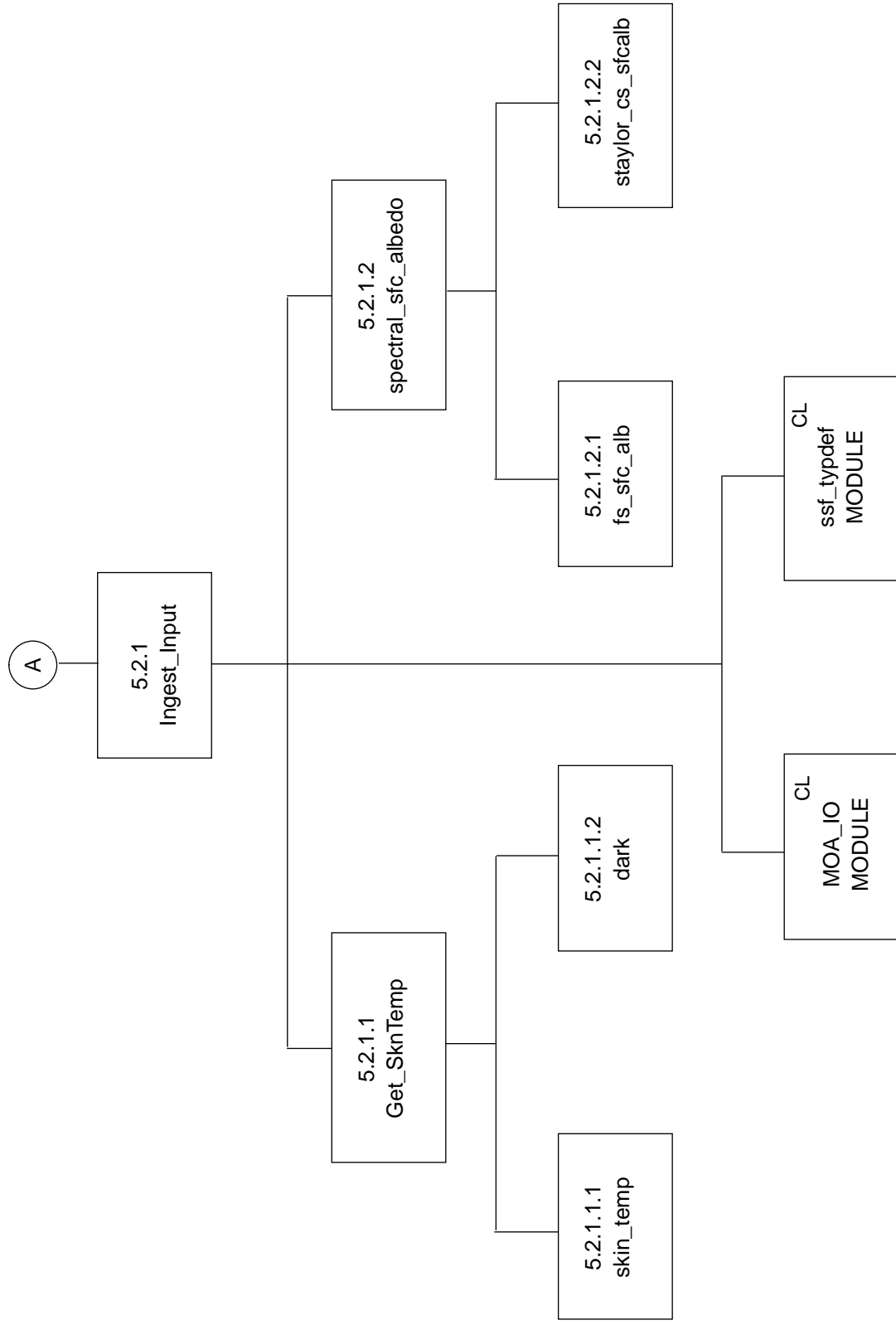


Figure 5-1. Flow Diagram of SARB Subsystem Processing



CL - CERESlib

Figure 5-2. Structure Chart for SARB Subsystem 5.0 (1 of 4)



CL - CERESlib

Figure 5-2. Structure Chart for SARB Subsystem 5.0 (2 of 4)

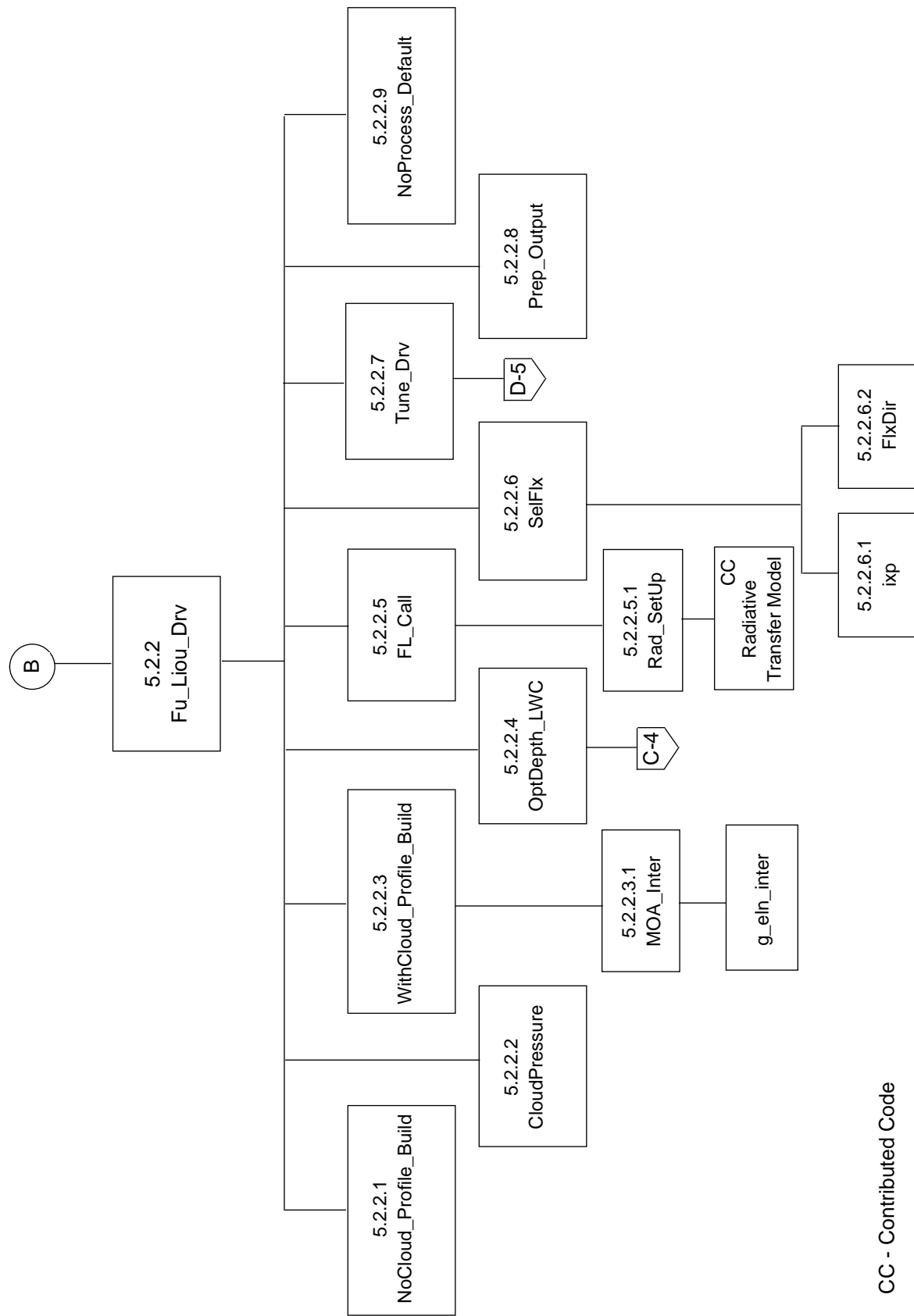
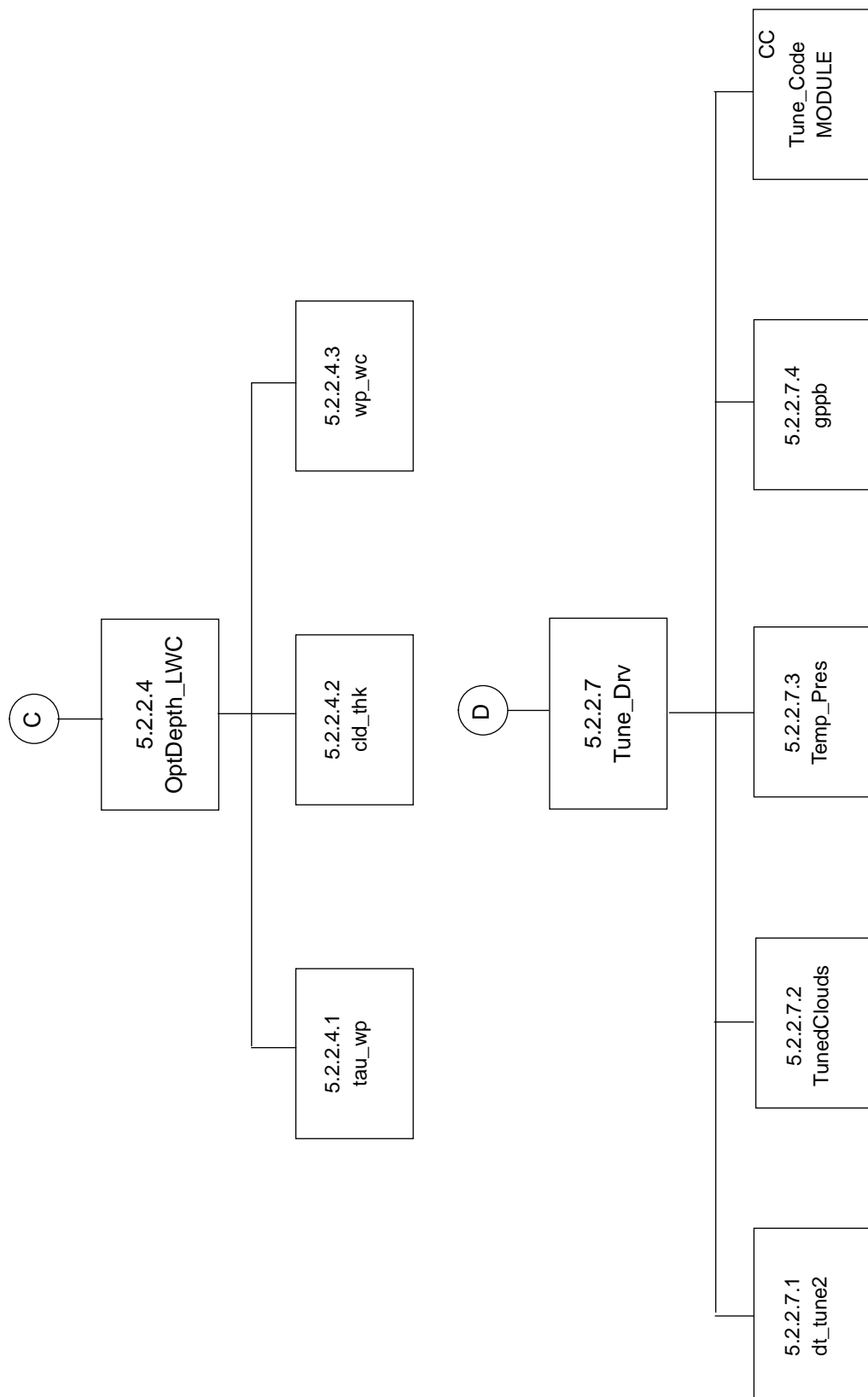


Figure 5-2. Structure Chart for SARB Subsystem 5.0 (3 of 4)



CC - Contributed Code

Figure 5-2. Structure Chart for SARB Subsystem 5.0 (4 of 4)

Table 5-2. SARB Subsystem Routine Descriptions (1 of 2)

ROUTINE NAME	ROUTINE NUMBER	MODULE NAME	DESCRIPTION
SARB_Drv	5.0	N/A	Drives Subsystem processing
Start5	5.1	Init_SS5	Initializes Subsystem processing
GetJobParams	5.1.1	Init_SS5	Retrieves parameter values from command line that identify the data set processed by this run of the Subsystem
Open_DrivTab	5.1.2	Init_SS5	Opens the DrivTab files and stores their Unit numbers in an array (DrivTab_handles)
Foot_Proc	5.2	Foot_Drv	Drives processing of footprint data
Ingest_Input	5.2.1	Foot_Drv	Ingests SSF footprint and stores necessary data in variable module, retrieves corresponding MOA data according to hour and location
Get_SknTemp	5.2.1.1	SfcSkin	Drives the generation of the surface skin temperature to be used by the radiative transfer model
skin_temp	5.2.1.1.1	SfcSkin	Derives surface skin temperature
dark (Function)	5.2.1.1.2	SfcSkin	Limb-darkening correction
spectral_sfc_albedo	5.2.1.2	SARB_Albedo	Defines the broadband surface albedo for SARB purposes
fs_sfc_alb (Function)	5.2.1.2.1	SARB_Albedo	Reads Olson vegetative map
staylor_cs_sfcalb (Function) <sup>a</sup>	5.2.1.2.2	SARB_Albedo	Calculates clear-sky surface broadband albedo (Staylor)
Fu_Liou_Drv <sup>a</sup>	5.2.2	FL_SetUp	Drives implementation of Fu-Liou code
OptDepth_LWC <sup>a</sup>	5.2.2.1	Convert_OptDepth	Converts optical depth to liquid water content
tau_wp (Function) <sup>a</sup>	5.2.2.1.1	Convert_OptDepth	Converts visible optical depth to water path
cld_thk (Function) <sup>a</sup>	5.2.2.1.2	Convert_OptDepth	Computes cloud thickness
wp_wc (Function) <sup>a</sup>	5.2.2.1.3	Convert_OptDepth	Converts water path to water content
NoCloud_Profile_Build <sup>a</sup>	5.2.2.2	FL_SetUp	Constructs vertical profiles of pressure, temperature, specific humidity, and ozone from input MOA data for use by the radiative transfer model
CloudPressure <sup>a</sup>	5.2.2.3	FL_SetUp	Builds a single array of pressure-ordered cloud top and bottom pressures from two separate arrays

Table 5-2. SARB Subsystem Routine Descriptions (2 of 2)

ROUTINE NAME	ROUTINE NUMBER	MODULE NAME	DESCRIPTION
WithCloud_Profile_Build <sup>a</sup>	5.2.2.4	FL_SetUp	Constructs vertical profiles of pressure, temperature, specific humidity, and ozone from input MOA data and cloud pressure levels for use by the radiative transfer model
MOA_Inter <sup>a</sup>	5.2.2.4.1	FL_SetUp	Linearly interpolates MOA data for floating pressure levels
g_eln_inter (Function) <sup>a</sup>	N/A <sup>b</sup>	ceres_meteor	Vertically interpolates profile data (linear, logarithmically)
FL_Call <sup>a</sup>	5.2.2.5	FL_SetUp	Acts as the interface with contributed FORTRAN 77 code for each cloud condition contained within the current footprint/region
Rad_SetUp <sup>a</sup>	5.2.2.5.1	rad_aer2.f	Provides an interface between contributed code developed in FORTRAN 77 and newly developed CERES DMT code in F90
SelFlx <sup>a</sup>	5.2.2.6	Lev_Isolate	Drives the isolation of the vertical profile levels that will be written to the output product
ixp (Function) <sup>a</sup>	5.2.2.6.1	Lev_Isolate	Identifies index of pressure level within the "full" profile that will become part of the "subset" profile
FlxDiv <sup>a</sup>	5.2.2.6.2	Lev_Isolate	Calculates the heating/cooling rate of layer in deg/day between selected levels
Tune_Drv <sup>a</sup>	5.2.2.7	TuneDrive	Drives the SRB tuning process
dt_tune2 <sup>a</sup>	5.2.2.7.1	Tune_Code	Tuning code contributed by Science Team
TunedClouds <sup>a</sup>	5.2.2.7.2	TuneDrive	Determines cloud top and bottom pressures from adjusted cloud temperatures
Temp_Pres <sup>a</sup>	5.2.2.7.3	TuneDrive	Converts temperature to pressure
gppb (Function) <sup>a</sup>	5.2.2.7.4	TuneDrive	Finds cloud bottom pressure
Prep_Output <sup>a</sup>	5.2.2.8	FL_SetUp	Maps variables defined during processing into output variables defined by Module SARB_PARAMS
NoProcess_Default <sup>a</sup>	5.2.2.9	FL_SetUp	Sets SARB parameters to default in the event of a footprint/region with no usable input data
Finish5	5.3	Wrap_Up_SS5	Finalizes Subsystem processing
HeadWrite	5.3.1	Wrap_Up_SS5	Writes the CRS Header to a file

a. Also used by the Synoptic SARB Subsystem

b. No number assigned - this routine will be submitted to CERESlib for Release 2

## 7.2 Synoptic SARB (Subsystem 7.2)

Both the Instantaneous SARB and the Synoptic SARB Subsystems use the same contributed code for the radiative transfer model and the tuning process (input sigma values to the tuning process may differ between the two Subsystems, however). Both Subsystems also use the same logic developed by the CERES Data Management Team to build the vertical profiles of meteorological and ozone data required by the radiative transfer model. The differences between the two Subsystems pertain only to the input and output products. Descriptions for all of the input and output products for the Synoptic SARB Subsystem are given in [Appendix A](#).

The Instantaneous SARB Subsystem ingests the SSF product produced by the Clouds and CERES Inversion Subsystems, while the Synoptic SARB Subsystem ingests Time Space Interpolate (TSI) data generated by the Time Interpolation Subsystem. Since the structures of these two products are different, the two SARB Subsystems require different software to ingest their primary input data. Similarly, the Instantaneous SARB Subsystem produces the CRS product, while the Synoptic SARB produces the SYN product. Due to the different structures between the two products, the two Subsystems require different software to write their primary output products.

The Instantaneous SARB Subsystem ingests its primary input data from one SSF file, while the Synoptic SARB Subsystem must read its primary input data from multiple TSI files. A breakdown of the TSI files is given in [Section A.1.5](#). The Synoptic SARB Subsystem is designed for the possibility of processing data for every CERES region in a single run. Since the TSI products will only contain data for regions for which data are available, there is no one-to-one correspondence between the region number and the record number. Consequently, an additional file containing the TSI record numbers for each CERES region is necessary. This file is the TSI Secondary Index File. Likewise, no record will be written to the SYN output product for regions with no available data, again eliminating a one-to-one correspondence between region number and record number. This necessitates the use of the SYN Secondary Index File.

A structure chart of the routines unique to the Synoptic SARB Subsystem is shown in [Figure 7.2-1](#). [Table 7.2-1](#) lists the functions of these routines, along with the routine numbers and the names of the FORTRAN 90 modules in which they are contained.

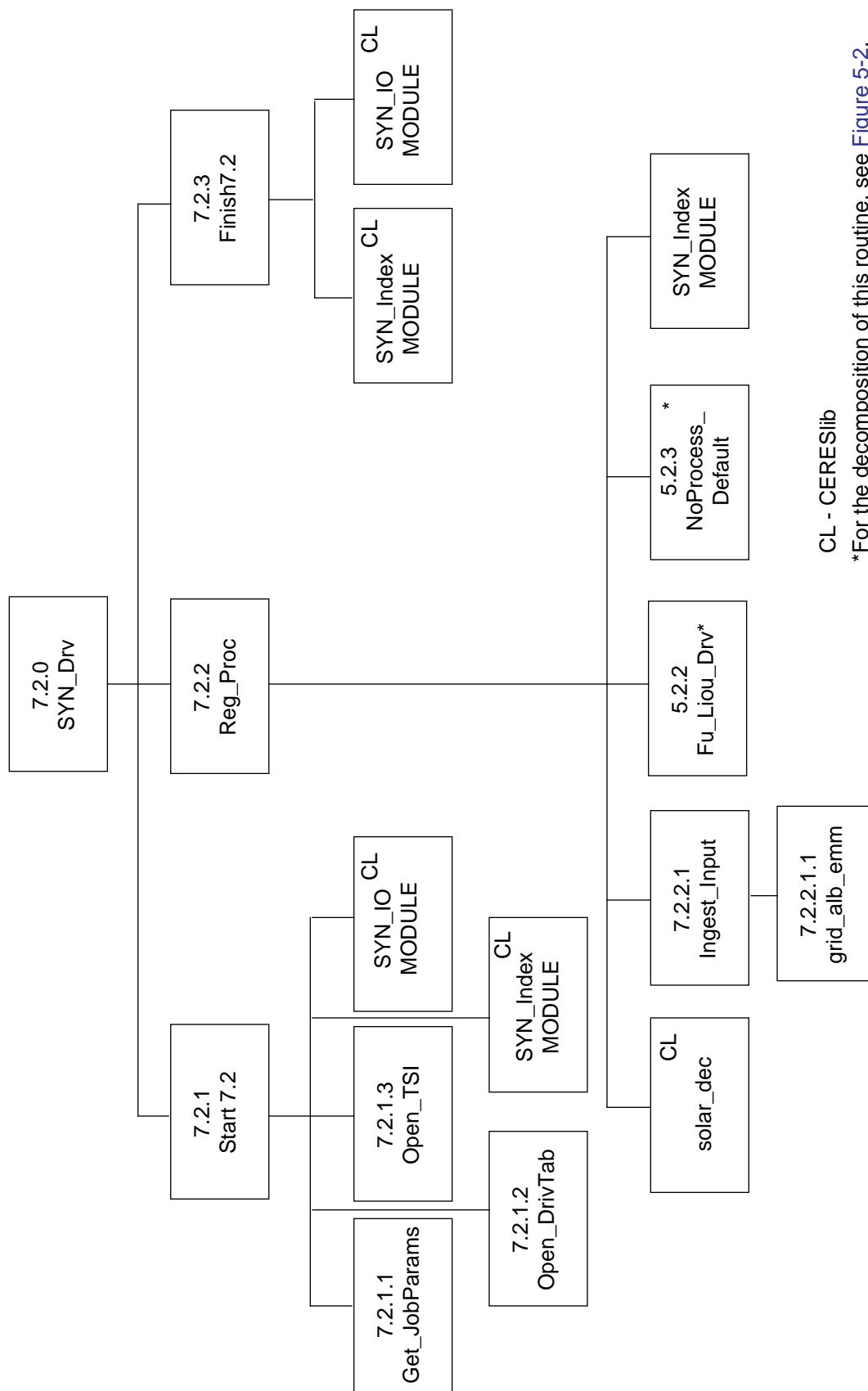


Figure 7.2-1. Structure Diagram of Synoptic SARB Subsystem

Table 7.2-1. Synoptic SARB Subsystem Routine Description

ROUTINE NAME	ROUTINE NUMBER	MODULE NAME	DESCRIPTION
SYN_Drv	7.2.0	N/A	Drives Subsystem processing
Start7_2	7.2.1	Init7_2	Initializes Subsystem processing
GetJobParams	7.2.1.1	Init7_2	Retrieves parameter values from command line that identify the data set processed by this run of the Subsystem
Open_DrivTab	7.2.1.2	Init7_2	Opens the DrivTab files and stores their Unit numbers in an array (DrivTab_handles)
Open_TSI	7.2.1.3	Init7_2	Opens TSI input files
SYN_IndexOpen	N/A	SYN_Index	Opens SYN secondary index file
Reg_Proc	7.2.2	Reg_Drv	Drives processing of regional data
Ingest_Input	7.2.2.1	Reg_Drv	Ingests TSI regional data and stores necessary data in SARB_Var module, retrieves corresponding MOA data
grid_alb_emm	7.2.2.1.1	SynSARB_Albedo	Defines the broadband surface albedo for Synoptic SARB purposes
Finish7_2	7.2.3	Wrap_Up_SS7_2	Finalizes Subsystem processing
SYN_IndexClose	N/A	SYN_Index	Closes SYN secondary index file

## **Abbreviations and Acronyms**

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTR	Atmospheric Structures
CERES	Clouds and the Earth's Radiant Energy System
CRS	Cloud Radiative Swath
DAAC	Distributed Active Archive Center
deg	degree
DRIVTAB	Derivative Tables
EOS	Earth Observing System
EOS-AM	EOS Morning Crossing Mission
EOS-PM	EOS Afternoon Crossing Mission
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
F90	FORTRAN90
MOA	Meteorological, Ozone, and Aerosol
NASA	National Aeronautics and Space Administration
NCEP	National Center for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
SAGE	Stratospheric Aerosols and Gases Experiment
SARB	Surface and Atmospheric Radiative Budget
SRC	Surface Radiative Properties Climatology
SSF	Single Satellite Fluxes
SYN	Synoptic Radiative Fluxes and Clouds
TOA	Top-of-the-Atmosphere
TRMM	Tropical Rainfall Measuring Mission
TSI	Time Space Interpolate

## **APPENDIX A**

### **External Interfaces**

## Appendix A

### External Interfaces

#### A.1 Input Products

##### A.1.1 Derivative Tables

The DRIVTAB product will contain precomputed tables consisting of the finite difference approximations of the derivatives required by the SARB tuning process. The derivatives are the change in TOA fluxes with respect to a small change in a selected tuning parameter, while other input parameters remain fixed. DRIVTAB will contain derivatives of TOA fluxes with respect to several different tuning parameters. These values have been computed and supplied by the SARB Working Group.

The Release 1.0 derivative tables used in the SARB tuning process are divided among four files according to either longwave flux or shortwave albedo and either clear-sky or total-sky conditions. Each file contains a separate table for each variable that can be tuned for that particular flux or albedo and cloud condition. Each tuning variable then has an entry that describes the change in flux or albedo for a predefined perturbation to that variable for a number of states. These states are selected according to their sensitivity on that flux or albedo. Please note that every file does not contain all of the tuning variables and all of the states. The number of states represents the dimensionality of the table; therefore, the size of the table increases rapidly with the number of states. The current maximum is six states, and the number of entries per state variable must be kept small to prevent unreasonably large file sizes. [Table A-1](#) lists the tuning variables and their associated state variables, along with the total number of derivatives, for each file.

The size of each file is equal to

$$NTV * (NESV_1 * NESV_2 * ... * NESV_n)$$

where the NTV variable is the number of tuning variables contained in the file, and the NESV variables are the number of entries for a state variable associated with the tuning variables in the file.

Each derivative table file includes information on:

- Table layout (number of tuning variables, number of states, number of entries per state)
- Perturbation magnitudes
- State values for each node

Table A-1. Derivative Table File Descriptions

FILE	TUNING VARIABLES (PERTURBATION)		STATE VARIABLES (NUMBER ENTRIES/STATE)		NUMBER DERIVATIVES IN FILE
Clear-sky LW flux	Surface skin temperature	(1K)	Surface skin temperature	(30)	1,200
	In (Precipitable water) (cm)	(0.1)	Precipitable water	(20)	
Total-sky LW flux	Surface skin temperature	(1K)	Surface skin temperature (K)	(30)	1,080,000
	In (Precipitable water) (cm)	(0.1)	Precipitable water (cm)	(20)	
	In (Cloud water path) (gm <sup>-2</sup> )	(0.1)	In (Cloud water path) ( gm <sup>-2</sup> )	(15)	
	Cloud top temperature (K)	(1K)	Cloud top temperature (K)	(15)	
			Cloud particle size (μm)	(2)	
Clear-sky SW albedo	In (Precipitable water) (cm)	(0.1)	Precipitable water (cm)	(3)	13,500
	Surface albedo	(0.01)	Surface albedo (frac)	(10)	
	In (Aerosol optical depth)	(0.5)	In (Aerosol optical depth) ( gm <sup>-2</sup> )	(5)	
			Cosine solar zenith angle (0-1)	(10)	
			Aerosol type--continental, maritime, urban (0-3)	(3)	
Total-sky SW albedo	In (Precipitable water) (cm)	(0.1)	Precipitable water (cm)	(3)	108,000
	Surface albedo	(0.01)	Surface albedo (frac)	(10)	
	In (Cloud water path) (gm <sup>-2</sup> )	(0.1)	In (Cloud water path) ( gm <sup>-2</sup> )	(15)	
	Cloud top temperature (K)	(1K)	Cloud top temperature (K)	(3)	
			Cloud particle size (μm)	(2)	
			Cosine solar zenith angle (0-1)	(10)	

### A.1.2 Meteorological, Ozone, and Aerosol (MOA)

The MOA is produced by the CERES Regrid MOA Subsystem. Each MOA file contains meteorological, ozone, and aerosol data for one hour and is used by several of the CERES subsystems. Data on the MOA are derived from several data sources external to the CERES system, such as the National Centers for Environmental Prediction (NCEP), the Stratospheric Aerosols and Gases Experiment (SAGE), and various other sources. These data arrive at intervals ranging from four times daily to once a month and are horizontally and vertically organized differently from what the CERES system requires. The Regrid MOA Subsystem interpolates these data temporally, horizontally, and vertically to conform with CERES processing requirements.

Prior to an EOS-wide review of each project's Algorithm Theoretical Basis Documents in May 1994, the MOA was referred to as the Atmospheric Structures (ASTR) file. At the request of the review panel, the name of this file was changed so as to avoid confusion with another EOS project, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER).

MOA data pertinent to the SARB Subsystems include:

- Surface temperature and pressure
- Vertical profiles of temperature, specific humidity, and ozone mixing ratios as a function of pressure for the internal atmospheric levels requested by the Clouds and SARB Working Groups
- Column precipitable water
- Total column ozone
- Total column aerosol optical depth

### **A.1.3 Surface Radiative Properties Climatology for Instantaneous SARB (SRC\_Instantaneous)**

The SRC\_Instantaneous product contains broadband albedo values for the adjustment of the shortwave surface spectral albedo values supplied by the Clouds Subsystem on the SSF product. These albedo values are based on monthly averaged total-sky albedo data calculated by a technique developed by Frank Staylor (NASA LaRC/ASD, retired). These albedo values are enhanced to a 10-minute grid, and are based on surface scene types from the Olson vegetative map overlaid with snow and ice data. For CERES footprints for which an instantaneous clear-sky retrieval using the Staylor surface albedo method is not possible, the adjusted spectral albedo values for each Fu-Liou spectral interval is determined by the following equation:

$$SA\_Adj_i = (BBAIb) / (BBAIb\_UnAdj) * SA\_UnAdj_i$$

where

$SA\_Adj_i$  = Adjusted surface spectral albedo for Fu-Liou interval  $i$

$SA\_UnAdj_i$  = Unadjusted surface spectral albedo from the SSF for Fu-Liou interval  $i$ , based on the Olson vegetative map

$BBAIb\_UnAdj$  = Unadjusted broadband surface albedo supplied on the SSF, based on the Olson vegetative map

$BBAIb$  = Total-sky default broadband surface albedo value contained on the SRC\_Instantaneous product

For Release 2, an additional file of adjustments is proposed. This file would contain a history of previously retrieved Staylor broadband clear-sky surface albedo values stored on a 10-minute grid and corrected to the cosine of a 0-degree solar zenith angle.

#### **A.1.4 Single Satellite Flux (SSF)**

The SSF product contains data for CERES footprints measured during a single hour from a single satellite. SSF data pertinent to the Instantaneous SARB Subsystem include:

- Time and location (footprint, satellite and Sun) data
- Cloud imager pixel information, such as cloud top pressure, effective temperature, cloud cover fractions, optical depth and particle size, averaged over the CERES footprint
- TOA fluxes estimated by the CERES inversion process

To read SSF data, the Instantaneous SARB Subsystem uses the FORTRAN 90 module `ssf_typdef`. This module contains the structure and variable names for the SSF product, along with the routines required for input and output operations.

#### **A.1.5 Time Space Interpolation (TSI)**

The TSI product contains CERES footprint data measured by multiple satellites and averaged over the CERES regions at 3-hour synoptic intervals. TSI data pertinent to the Synoptic SARB Subsystem include:

- Julian time and CERES region number
- Cloud information, such as cloud top pressure, effective temperature, cloud cover fractions, optical depth, and particle size
- TOA fluxes estimated by the CERES inversion process

To read TSI data, the Synoptic SARB Subsystem uses the FORTRAN 90 module `tsi_typdef`. This module contains the structure and variable names for the TSI product, along with the routines required for input and output operations.

There are eight synoptic hours per day and up to 26410 (Release 1 only) CERES regions that may contain data for each hour. All data throughout the month for the same region and daily synoptic hour are stored together on a single TSI file. For purposes of storing the TSI data in files of manageable sizes, each CERES region is assigned to one of five subsets, with a separate TSI file for each subset. For example, all data for the first synoptic hour of every day of the month and regions within the first subset are stored in one file, and all data for the first synoptic hour and regions within the second subset are stored in a second file. All data for the second synoptic hour and regions within the first subset are stored in a third file, and all data for the second synoptic hour and regions within the second subset are stored in a fourth file. There is a file for each synoptic

hour and each subset of regions for a total of 40 files for a given month. [Table A-2](#) lists which files contain data for which synoptic hour and which subset of regions.

Table A-2. Monthly TSI File Numbers

DAILY SYNOPTIC HOUR	REGIONS 1 - 5282	REGIONS 5283 - 10564	REGIONS 10565 - 15846	REGIONS 15847 - 21128	REGIONS 21129 - 26410
1	File 1	File 9	File 17	File 25	File 33
2	File 2	File 10	File 18	File 26	File 34
3	File 3	File 11	File 19	File 27	File 35
4	File 4	File 12	File 20	File 28	File 36
5	File 5	File 13	File 21	File 29	File 37
6	File 6	File 14	File 22	File 30	File 38
7	File 7	File 15	File 23	File 31	File 39
8	File 8	File 16	File 24	File 32	File 40

#### A.1.6 TSI Secondary Index File

Since data for every CERES region will not always be available and the TSI product only contains data for those regions that are available, the TSI record numbers for each region and hour cannot be predicted. The Synoptic SARB Subsystem requires data for all available regions for a single hour per run. To enable the Synoptic SARB Subsystem to know which TSI record contains a selected region's data for a selected time, a file of secondary indexes provides the record numbers for each region for each hour. There is one TSI secondary index file per month, and each file contains 248 records--one record for each synoptic hour of the month with one element for each CERES region. [Table A-3](#) lists the organization of the TSI secondary index file. Given the hour and region number, the TSI file number can be calculated, and the record number obtained from the secondary index file is the record number within that TSI file. If a region is not available for a particular hour, that secondary index value is set equal to zero. Given the corresponding record number, the Synoptic SARB Subsystem can ingest TSI data using the FORTRAN direct access technique.

Table A-3. TSI Secondary Index File Structure

RECORD NUMBER	TSI SECONDARY INDEX FILE CONTENTS
1	Record number for CERES Region 1, monthly synoptic hour 1 Record number for CERES Region 2, monthly synoptic hour 1     Record number for CERES Region 26410, monthly synoptic hour 1
2	Record number for CERES Region 1, monthly synoptic hour 2 Record number for CERES Region 2, monthly synoptic hour 2     Record number for CERES Region 26410, monthly synoptic hour 2
248	Record number for CERES Region 1, monthly synoptic hour 248 Record number for CERES Region 2, monthly synoptic hour 248     Record number for CERES Region 26410, monthly synoptic hour 248

### A.1.7 Surface Radiative Properties Climatology for Synoptic SARB (SRC\_Synoptic)

The SRC\_Synoptic contains Staylor broadband spectral surface albedo data for each of the Fu-Liou spectral intervals for each CERES region. These spectral albedo values are based on percentages of the 10-minute surface scene types (see [Section A.1.4](#)) contributing to the CERES grid, in conjunction with the surface spectral properties map used by the Clouds Subsystem.

For Release 2, an additional file is proposed. This file would contain a history of previously retrieved Staylor broadband clear-sky surface albedo values corrected to the cosine of a 0-degree solar zenith angle.

## **A.2 Output Products**

### **A.2.1 Cloud and Radiation Swath (CRS)**

The CRS contains all of the SSF data for each footprint, in addition to the modeled flux profiles derived during Subsystem processing. For each footprint, the CRS will also contain the adjustments made to the adjustable input parameters, such as cloud height and aerosol optical depth. The differences between the initial (untuned) and final (tuned) flux values will also be stored on the CRS.

### **A.2.2 Synoptic (SYN) Product**

The SYN contains regionally averaged cloud properties, TOA fluxes estimated by the CERES inversion process, and vertical flux profiles for the CERES synoptic hours. All data on the TSI product, whether used by the Synoptic SARB Subsystem or not, are included in the SYN product. The TSI input product provides the cloud properties and TOA flux values, while the vertical flux profiles are calculated by the Synoptic SARB Subsystem.

Since there are eight synoptic times for a day, there will be eight SYN products in a single file. As a single run of the Synoptic SARB Subsystem processes data for one hour only, data on this file are grouped according to hour. Within an hour's data, the data are organized according to CERES region number. Data will only be written to the SYN for regions for which data are available, thus the number of SYN records per hour will vary.

### **A.2.3 SYN Secondary Index File**

Since data for every CERES region will not always be available and the SYN product only contains data for those regions that are available, there is not a one-to-one correspondence between the SYN record numbers and CERES region numbers. The SYN Secondary Index File contains the record numbers for the regions for which data are available.

There is one SYN secondary index file per month. It is dimensioned as the number of CERES regions by the number of synoptic hours in a 31-day month. [Table A-4](#) lists the organization of the SYN Secondary Index File. Each value gives the record number of SYN data for a given region for a given hour. Given the hour, the daily SYN file can be determined and the record number obtained from the secondary index file is the record number within that daily SYN file. If data for a given region and hour are unavailable, then the corresponding value in the secondary index file is set equal to zero.

Table A-4. SYN Secondary Index File Structure

RECORD NUMBER	SYN SECONDARY INDEX FILE CONTENTS
1	Record number for CERES Region 1, monthly synoptic hour 1 Record number for CERES Region 1, monthly synoptic hour 2     Record number for CERES Region 1, monthly synoptic hour 248
2	Record number for CERES Region 2, monthly synoptic hour 1 Record number for CERES Region 2, monthly synoptic hour 2     Record number for CERES Region 2, monthly synoptic hour 248
.	
26410	Record number for CERES Region 26410, monthly synoptic hour 1 Record number for CERES Region 26410, monthly synoptic hour 2     Record number for CERES Region 26410, monthly synoptic hour 248

#### A.2.4 Last Record Written File

Since the Synoptic SARB Subsystem processes an hour at a time and the number of SYN records per hour varies, the number of the last record written for an hour to a daily SYN file must be tracked. The last record file contains an array of 31 elements--one for each day of the month--that indicates the number of the last record written to each of the daily files. As more hours for a given day are processed through the Synoptic SARB Subsystem, the value of the corresponding array element increases. This file is updated at the end of Subsystem processing.

## **APPENDIX B**

### **Data and “Constants”**

## **Appendix B**

### **Data and “Constants”**

The text for this appendix will be included in a later version of this document.

## **APPENDIX C**

### **Error Messages**

## **Appendix C**

### **Error Messages**

The text for this appendix will be included in a later version of this document.

## **APPENDIX D**

### **Structure Chart Symbols**

## Appendix D

### Structure Chart Symbols

The following symbols are used in the structure and flow charts in [Figure 5-1](#), [Figure 5-2](#), and [Figure 7.2-1](#):

Figure D-1. Structure Chart Symbols

